ng three or four. When I finally got out in the wilderness collapsed with heatstroke, because I was not really in red myself and everyone in my group, because I was not w the need to want to feel that you are doing well and do- we are not real about where we are, we are not going to l to do to survive in this wilderness."

seem to realize, he added, that it is not like we're on the have to avoid the iceberg. *We've already hit the iceberg.* hing in down below. But some people just don't want to floor; others don't want to give up on the buffet. But if we hard choices, nature will make them for us. Right now, ness of the true scale and speed of this problem remains to the expert scientific community, but soon enough it ly obvious to everyone.

e wrong: I take succor from the number of young people by this issue. And as the Greenasathistle.com blogger l, "it's better to be hypocritical than apathetic when it vironment"—as long as you know that's what you're do- ou keep moving in the right direction, and as long as you ely declare victory. It's planting our flag prematurely that the most trouble. And that's what we've started doing brand, some green buzz, a green concert, and we're on ing the problem. Not a chance.

we were climbing Mount Everest and we reached base owest rung on the mountain climb, and decided to look wn our gear, pat our Sherpas on the back, and open a cel- y," said Jack Hidary, the energy entrepreneur. "But mean- Everest, all 29,000 feet of it, still looms before us."

d it actually look like from the top of Mount Everest? That a truly disruptive and transformational clean power revo- e? Turn the page.

TEN

The Energy Internet: When IT Meets ET

Revolution is not a dinner party, not an essay, nor a painting, nor a piece of embroidery; it cannot be advanced softly, gradually, carefully, considerately, respectfully, politely, plainly and modestly.

—Mao Tse-tung

That view from Mount Everest would look like nothing you've ever seen. Actually, being a part of it would be like nothing you've ever experienced, either. It would feel like all the power systems in your home were communicating with all the information systems in your home and that they had all merged into one big seamless platform for using, storing, generating, and even buying and selling clean electrons. It would feel like the information technology revolution and the energy technology revolution, IT and ET, had merged into a single system. It would feel like you were living with an "Energy Internet."

I realize this may sound like science fiction or magic. But it's not. Many of the technologies that would make up an Energy Internet—a term used by *The Economist* to refer to the "smart grid"—already exist or are being perfected right now in garages and laboratories. What we need most now are the integrated government policies—laws and standards, taxes and credits, incentives and mandates, minimums and maximums—to guide and stimulate the marketplace to drive that innovation further, to commercialize these new ideas faster, and to bring this revolution to life sooner.

This chapter is the first of four that will describe what a system of clean power, energy efficiency, and conservation would look like and how we might bring it about. This chapter will describe how an Energy Internet would enable you, me, and your next-door neighbor to do extraordinary things by way of saving energy and using clean power efficiently, and do them around the clock, all the time, whether or not you're thinking about it. The next two chapters will describe the integrated government policies we need to guide and stimulate our businesses and investors to commit the capital we'll need to erect such an Energy Internet and to invent the abundant, clean, reliable, and cheap electrons we would need to feed it. Those will be followed by a chapter on preservation: how we can also create the policies for the preservation of the natural world—the plants, animals, fish, oceans, rivers, and forests that sustain life.

Taken all together, these chapters will explain what an REEFIGDCPEERPC < TTCOBCOG—a renewable energy ecosystem for innovating, generating, and deploying clean power, energy efficiency, resource productivity, and conservation < the true cost of burning coal, oil, and gas—actually looks like in the real world.

While many of the raw materials necessary to make this system a reality already exist in some form, it will not be easy to implement—no revolution is. But this definitely is not science fiction. So keep an open eye and an open mind, and remember what the late, great science fiction writer Arthur C. Clarke famously observed: "Any sufficiently advanced technology is indistinguishable from magic."

Before we lift the curtain on this magic show, I first need to do something really mundane. I need to explain how our current electricity system in America, primarily based on a network of publicly regulated utilities, actually works. Probably the last time you stopped and thought about utilities was when you landed on one in Monopoly and had to decide whether to shell out $150 to buy the Electric Company. That was certainly the case for me before I started researching this book. I knew how my car worked and where the closest gasoline station was. I knew where my local water tower and pumping stations were. But I knew absolutely nothing about this thing called an electric utility, which provided the electrons that powered my life every day. I knew we got an electric bill once a month and paid it, but that's about it. Well, our power utilities are more interesting than you think—and they are also more critical to getting the Code Green revolution right than people realize.

You may think you can skip this part. Don't. Love them or hate them, local and regional regulated electric utilities are going to remain at the heart of our nation's energy system for a long time. If we are going to build a clean energy platform, it will be largely through the actions implemented by and through America's electric utilities. They have the customer base, the ability to raise huge volumes of cheap capital, and the installed technology infrastructure that we need to drive the development of an Energy Internet. And the public trusts utilities. It is no accident that when people want to commit fraud, one of their favorite strategies is to knock on someone's door dressed as a service person from the local power company. Hey, come right in!

So how has this utility system worked up to now? The electric-utility-centric power system that exists today in the United States, and most other countries, was constructed according to one overarching principle: the obligation to serve load. This came about as the result of an arrangement in which local and state governments, and the regulatory boards they spawned, granted monopolies to power companies ("utilities") to provide electricity or natural gas to customers in a certain region. In return, those utilities were obligated to do three things: to provide *reasonably priced power*, provide *reliable power* (electricity that could be counted on 24/7/365), and provide *ubiquitous power* (power that would be available to every customer who wanted electricity in that utility's region of operation).

This was a system that Samuel Insull, the commercial protégé of Thomas Edison, crafted and sold to government agencies over one hundred years ago. It provided tangible benefits to utilities—which could raise funds cheaply and efficiently to make the big power plant and transmission investments, because they were guaranteed a customer base—and to customers, who for decades got cheap, reliable, and ubiquitous power. Most publicly regulated utilities lived up to this bargain very well, powering America's growth throughout the twentieth century.

(The utility regulators who set the rates are typically called public utilities commissions. The commissioners are usually appointed by the state governor or legislature, while regulation of interstate electronic commerce is handled from Washington by the Federal Energy Regulatory Commission.)

But there were downsides to this largely state-by-state system. To begin with, it is often said that the American electricity grid that evolved over the years, with all its power stations and transmission lines, is the biggest machine man has ever made. It may or may not be. But one thing I can tell you for sure about this grid—it is the dumbest big machine man ever made, and it isn't just dumb in one way.

I know I am being a bit unfair here. In terms of raw scope, the electrification of America's homes, towns, and factories, wherever they were, was truly one of the great engineering feats of the twentieth century. Our economy would not be where it is today without that achievement. But while this grid was indeed ubiquitous and reliable and provided cheap power, it was not built with any intelligent design. It just emerged, utility by utility, service territory by service territory, balance sheet by balance sheet, local market rules by local market rules. America, to this day, has no true national grid. It's actually a national patchwork that makes the Balkans look unified.

Today there are almost 3,200 electric utility companies in America, some of which have service territories spanning huge swaths of multiple states, while others serve just a single township or part of a county. Eventually these electric companies and their power lines coalesced into three regional grids in America: the Eastern Interconnection, which includes the eastern U.S. seaboard, the Plains states, and the eastern Canadian provinces; the Western Interconnection, which continues all the way to the Pacific, except in Texas, which has its own grid—ERCOT, the Electric Reliability Council of Texas. That's it. That's our electricity system.

There is surprisingly limited integration between these regional grids and even between the individual utilities within each region. Imagine trying to drive across America, from New York to Los Angeles, without our interstate highway system—taking just state and local highways—and using only county maps to figure out where you were going. That's what it would be like to try to send electrons from New York to Los Angeles. The fact is, you wouldn't really want to send electrons across the country, because too much electricity would be lost in transmission. But this patchwork is still a problem. It is very difficult just to move electrons around within regions. Imagine trying to drive even from Phoenix to Los Angeles only on local roads, and you have an idea of what it is like to try to move electrons generated at wind farms in northern Arizona to markets in southern California.

The system is also dumb in terms of pricing. Our utilities deliver electric power very reliably, but the electrons they sell are totally undifferentiated electrons. That is, in most cases you pay the same amount for electricity that comes into your home no matter how it is generated—coal, oil, nuclear, hydro, wind, solar, or natural gas—and no matter what

time of day it is generated, whether at peak or off-peak demand periods. You cannot differentiate. You pay one price per kilowatt-hour and get one bill, whenever the electric company gets around to reading the meter on the back wall of your house. There's nothing in the electric power industry today that even remotely compares to the detail of a telephone bill.

Finally, the utility system is dumb in that, in most cases, there is no two-way communication between you and your utility. You as a consumer cannot demand, and the utility cannot provide, a specific kind of electricity generation for a specific price to a specific machine. And when the power to your house goes out, in most of the United States, you have to telephone the electric company and let them know. The utility has no other way of knowing.

But God bless the grid; while it is really dumb, the electricity it has provided was, for many years, cheap, and always ubiquitous and reliable—so reliable that most Americans have never even asked themselves where it came from, how it is made, or how it winds up being immediately available to flow out of the wall sockets on demand. We just expect it to be there, and when it isn't, even for fifteen minutes, there is hell to pay.

The state-appointed regulatory boards tell each utility operator how much it can charge for every kilowatt-hour of electricity. The regulator basically instructs the utility: "You will generate cheap, reliable, ubiquitous power, we will give you a monopoly to do so, and every few years we will determine the rate at which you can serve load in your area to ensure that your expenses are recovered and that you get a proper return on capital to run the business—provided you do your job right."

Specifically, the regulator and the utility operator work out a plan—sometimes called an integrated resource plan, other times just a plain-vanilla capital budget. In this plan, the utility operator tells the regulator, "Here is how I intend to serve my customers and meet my obligations to provide ubiquitous power as cheaply and reliably as I can—with this many power plants and power lines, costing this much money." And once that is approved, the operator says to the regulator, "I will need to recover this much money to cover all these costs."

And so the regulator takes the utility's statement of its monetary needs (called a revenue requirement), chops it down a bunch—because the initial request is usually bloated—and then divides it by the kilowatt-hours the utility is expected to sell. That becomes the price per kilowatt-hour, which the utility then charges the consumer for electricity. That price is calculated to cover the utility's fixed cost of operating its existing power plants and the cost of investing in new plants, as well as the variable costs of the fuel that goes into generating the electricity—that is, the coal, oil, natural gas, or uranium—plus the costs of labor, taxes, and insurance, and then a cherry on top: some after-tax profit for shareholders.

To put it at its most simple: Utilities made their money by building stuff—*more power plants and more power lines that enabled them to sell more and more electrons to more and more customers*—because they were rewarded by their regulators with increased rates on the basis of those capital expenditures. The more capital they deployed, the more they made. And since their new capital investments had to be justified by growth in demand, the utilities were motivated to encourage consumption, which in turn created the need for them to invest and build more, which in turn triggered the reward of increased income. The cycle became almost Pavlovian.

"Think about a utility," said Ralph Cavanagh, the legendary utilities expert at the Natural Resources Defense Council, which has spurred innovation around utilities in California. "Their business involves enormous sunk costs that must be recovered regardless of how much energy they sell. If they invest in a new natural gas power plant or a wind farm, it can cost hundreds of millions of dollars, even billions. And those costs do not vary if you, the customer, use more or less power. So the utility had a vital interest in boosting electricity and natural gas sales so it could be sure to recover its fixed costs."

In many ways, your local utility was "like a big all-you-can-eat-for-five-dollars buffet," explained Peter Corsell, the CEO of GridPoint, which makes an apparatus that can manage all the power systems in your home. "They were paid by the regulators to provide us reliable, cheap, all-you-can-eat power." And we came to that buffet every day, and we ate whatever we wanted. And it was always open. And it was always cheap. Life was good.

One reason it was cheap, though, was that the public and the regulators never asked the utilities to serve two additional things at this electron buffet. We didn't ask that the power they generated be free of CO_2 emissions. (We asked that traditional pollutants, particularly mercury, nitrogen oxides, and sulfur oxides emitted during the coal combustion process, be removed, which the utilities did very well, but not carbon dioxide.) And we didn't encourage them to offer energy efficiency programs. We didn't encourage our utilities to reward consumers for saving energy or to

enable consumers to respond to changes in supply or prices, so they could buy more electricity when it was cheaper to generate and use less when it was more expensive to generate.

This emphasis on cheap trumped efficiency and global warming considerations. It made sure that utilities relied as much as possible on coal plants. And for many years, if utilities could deliver electricity at a nickel a kilowatt-hour, few people cared if those coal plants spewed out millions of tons of CO_2, and few people cared if you used those kilowatt-hours very inefficiently or in wasteful applications. In fairness, the regulators pressured the utilities to keep prices down and focus where possible on cheap sources like coal.

The mandates for "ubiquitous" and "reliable" also worked against efficiency. Why? Because they required utilities to overbuild their supply capacity so they always had an adequate "reserve margin"—at great cost, which was passed on to you—so they could always meet peak load demand on the very hottest days, which might occur only once or twice a summer. Adding supply was always the answer to every problem, never trying to manage demand.

But then one day a funny thing happened on the way to the all-you-could-eat electron buffet. A few people—like Al Gore—started to wander around out back into the kitchen, and what they saw there was not pretty. And then they came back to the front of the buffet line and told the rest of us: "Do you know what is going on out back? Do you know why this all-you-can-eat electron buffet costs only $5? It's because there are all sorts of costs being incurred that are not being passed on to us customers. They are being paid by someone else."

These costs were being paid by society at large or charged to our children's credit cards. In particular, the coal, natural gas, and oil that were generating all those cheap electrons for our all-you-can-eat buffets were causing global warming, childhood asthma, acid rain, deforestation, biodiversity loss, and petrodictatorship—and no one was factoring these costs into the price per kilowatt-hour you were paying. And since when something is free, or practically free, people usually demand more of it, more cheap electrons were demanded, and more destruction was occurring out back.

The people running these buffets are your neighbors and mine. They're not out to harm society. They're part of it. But the Dirty Fuels System was set up to reliably deliver all-you-can-eat electrons at the cheapest price to every customer who wanted them (and low-cost gasoline to every driver who wanted it) even if that meant devastating our ecosystems and climate as side effects. We just didn't make all the connections until recently—and many people still haven't.

Now the public consensus is shifting. Now we are beginning to understand that we need a new system—a *Clean Energy System*. We still want our electricity and fuels to be cheap, reliable, and ubiquitous, but now we also want them to come as much as possible from non-CO_2-emitting sources and via a system that promotes energy efficiency and conservation, not just consumption and pollution. To be more specific, roughly 40 percent of America's total CO_2 emissions come from the production of electricity used in homes, offices, and factories. Another 30 percent of American emissions come from the transportation sector—primarily cars, trucks, boats, trains, and airplanes. So if we could electrify all of our transportation fleet, save for airplanes, and make all of them, and our buildings too, vastly more energy efficient at the same time—and then supply this whole 70 percent, buildings and transportation, with clean, abundant, cheap, reliable electrons through a smarter grid—that would be a revolution. It would be a giant step toward reducing America's consumption of fossil fuels and our carbon footprint.

That's the real green revolution we are seeking. But it is still too abstract for most people. So let's hop into a time machine and see what it would actually be like to live inside a real green revolution in the year 20 E.C.E.—Energy-Climate Era.

20 E.C.E.

Your alarm goes off at 6:37 a.m., playing the Beatles classic "Here Comes the Sun" just as you programmed it to the night before from 10,000 wake-up songs offered by your utility in collaboration with your phone company and iTunes. You have no alarm clock. The music was actually playing out of your home phone speaker, which itself is integrated into your home Smart Black Box—or SBB as it is called. Everyone now has an SBB—your own personal energy dashboard. Just as when you sign up for cable television you get a set-top box or digital recorder with it, now, when you sign up for the Energy Internet with a progressive utility, like Duke Energy if you live in the Carolinas or Southern California Edison if you live out west, you get an SBB.

It is a microwave-oven-size black box that sits in your basement and integrates the controls and assures the interoperability of all your energy, communications, and entertainment devices and services. That includes your temperature settings and other energy preferences in every room, your lighting, your home alarm system, your telephones and computers and Internet connections, all your appliances, all your entertainment devices, and your plug-in hybrid electric car and its storage battery. The SBB's digital touch screen can tell you exactly how much energy any of these devices is consuming at any moment.

Your car, by the way, is no longer called a "car." It is now called a RESU, or rolling energy storage unit, as in "I drive a Ford Mustang RESU." The term "car" is now considered so, gosh, twentieth century.

That is not the only thing considered old school. In the early years of the Energy-Climate Era, we progressed from an Internet that connected computers and a World Wide Web that connected content and Web sites to an Internet of Things: an Energy Internet in which every device—from light switches to air conditioners, to basement boilers, to car batteries and power lines and power stations—incorporated microchips that could inform your utility, either directly or through an SBB, of the energy level at which it was operating, take instructions from you or your utility as to when it should operate and at what level of power, and tell your utility when it wanted to purchase or sell electricity. You and your utility now have two-way communications.

Your heating and air-conditioning units, your lighting, and all your appliances—your dishwasher, dryer, refrigerator, and car battery—can now be programmed to run at lower levels when demand for electricity on the grid is highest and electrons are most expensive, and they can be instructed to run at fuller power during the night—or, in the case of your electric car, to charge and store energy at night, when electricity demand is lowest and power is cheapest.

Have no fear: Signing up for this kind of system is totally voluntary. There is no Big Brother who will force you to do so. If you don't want to have an SBB in your house, you don't have to have one. You can still get your electricity the old-fashioned dumb way. But have no illusions: If you opt out, you will be thrown into a general customer pool and your rates will go up, because the utility will not be able to optimize the energy usage to or from or inside your home—and other customers will not be willing to pay higher rates to subsidize your wasteful and environmentally irresponsible behavior.

After you read the newspaper and have your morning coffee, you call up the control panel of your SBB on your iPhone or your BlackBerry or your home computer. This colorful, easy-to-read screen will tell you how much power every device in your home is using and how much each kilowatt-hour costs at that time of day on your personal energy plan.

That's right: your own personal energy plan. Your utility now offers a number of different plans, the way the phone company does, so you can program your home's energy use—for lowest cost, cleanest energy, maximum efficiency, or time of day you are at home or work, among many other choices.

The most popular option is the "Bargain Power—Nights and Weekends" plan. This plan helps your utility to both balance and reduce overall energy demand by shifting electricity loads from peak hours of the day and evening when electrons are most expensive to off-peak hours at night when they are cheapest. Through your SBB, your utility adjusts your home thermostat up or down, very slightly, and instructs your water heater, refrigerator, and air conditioner to cycle off for short periods of time—so short that you don't even notice. It also allows the utility to run your dishwasher and dryer overnight, and even to turn off all your exterior lights for a few minutes at a time.

In return for letting the utility manage your energy use in this way, you get a 15 percent reduction off your monthly electric bill. It is a great deal for the utility, because it can now use its existing power plants with greater efficiency—as the load peaks are being flattened and the load valleys are being raised—so it doesn't have to build new ones just for peak hours.

Another popular plan is the one called "Day-Trading for Electrons." Under this plan, your appliances can, in effect, become your surrogate energy shoppers. You program into your SBB that you want certain of your appliances (your dryer, your dishwasher, your hot water heater, your air conditioner) to run only when electrons cost less than 5 cents a kilowatt-hour and that you want your home cooling or heating system (depending on the season) to cycle down if electricity exceeds 10 cents a kilowatt-hour. (You will put on a sweater or open a window instead.) So you loaded the dishwasher before you went to bed, but it did not actually run until 3:36 a.m., when your SBB detected that the price of electrons had fallen to 4.9 cents a kilowatt-hour. And your air conditioner cooled the house all day, until about 6:00 p.m., when rates shot up to 12 cents a kilowatt-hour—then it automatically shut itself off. It came back on at 9 p.m., when the price of electrons fell to 9.9 cents a kilowatt-hour.

This is a far cry from Grandpa's day—pre–1 E.C.E.—when most utilities charged a flat rate per kilowatt-hour, regardless of actual demand and cost fluctuations. In this new era, all you do is choose the "Day-Trading" energy plan and your dishwasher and air conditioner, with their smart chips inside and working with your SBB, are day-trading electrons on your behalf, bidding into a real-time energy market every five minutes, to get the best price automatically.

Most consumers don't realize it, but the electricity market is an instantaneous, constantly shifting spot market, in which electricity costs bounce up and down as much as tenfold in the course of a day. Your very simple monthly bill with just one rate per kilowatt-hour masks this wild, gyrating electricity market going on every minute of every day, with prices changing depending on demand on your regional grid and available supplies from different coal or gas power plants, hydroelectric dams, wind farms, or nuclear facilities.

For instance, when demand on your regional grid outstrips the available supply of the cheapest electrons—those generated from coal—your utility has to call on its natural gas generators, which means that the cost of electrons to the utility immediately jumps to the cost of natural gas. When demand goes down, just the opposite happens, and the price might drop to the cost of cheap nuclear or hydro power. All of this was hidden in the Dirty Fuels System. But not anymore—not after you installed your SBB and smart appliances, and the utility installed much more intelligent technology on its grid, so your home could read the actual electricity costs from the utility and run discretionary appliances only when electricity hit your price points. Not only are you now using power when it is most cost-effective, but thanks to steadily rising efficiency standards, you are also using less power, period. Your appliances today use about one-third the electricity they needed to do the same tasks a decade ago.

With the smart grid, controlling your energy usage is as simple as turning the lights on and off. Under both these plans, you just press the "sleep" button on the SBB control panel when you walk out the door and all the lights and every appliance in the house will shut down or go to its lowest necessary power setting until instructed otherwise. You can call up your SBB control panel on your cell phone and tell your house to "wake up" the minute you land at the airport after a long trip, so by the time you get home the hot water is available in the shower and the air conditioner has cooled down the house.

Electricity is all about on/off, and the purpose of the smart grid is to make sure that whenever electricity is on, it is at is most productive. Why should all your appliances be on, sucking up what is called "vampire load," when you are not home? It is because your appliances are too dumb to know better. By turning appliances on and off at the right times, the smart grid can virtually eliminate the vampire loads that can consume up to 10 percent of all the power in a household. (Of course, when you do need to run your dryer or dishwasher at a particular time, you can just override the automatic controls, and the system will power the appliance using the cheapest power available at that moment.)

Your neighbor, who is a green fanatic, signed up for the "Fuels from Heaven/Fuels from Hell" plan. Under this plan, you pay a premium every month and the utility agrees to cover every kilowatt hour you use with clean power from wind, solar, geothermal, or hydro—so that you are using no fuels from hell. This doesn't mean that your power is coming from clean sources for every second of every day. It means that every month the utility has procured an amount of clean power—tied to specific and actual generation sources—equivalent to the demand of all those customers on the "Fuels from Heaven/Fuels from Hell" plan. You can feel better about your electricity usage because you are driving the utility to constantly access more clean power sources and thereby make them more cost-competitive.

You and your neighbors also got together and signed up for the "How Slow Can My Meter Go" plan. It works like this: Where the four corners of your backyards meet, you installed four tracking solar arrays. Again, you leased them from your utility. The solar power feeds directly into each of your four homes and actually slows down your electric meters—reduces the amount of power you need to take from the grid—by providing you with your own distributed power. Known as RGSUs—regional generation and storage units—the panels are maintained by your utility. Just the other day, the Duke Energy truck was out replacing two of your solar panels damaged in a hailstorm. No one had to call the company. Each panel is connected by the smart grid to Duke's supercomputer, so it could send a message immediately when a panel went down. What a contrast from the stories Grandpa used to tell about the days when a bad storm would sweep through the neighborhood and his house would lose power, but the electric company wouldn't even know until he telephoned them! What a pain that must have been, Grandpa!

The utility was happy to install the solar panels, both because it is a way to earn income through new services and because you live in a densely populated area where the grid can often get stressed at peak times—so having some customers use distributed power takes some pressure off the grid. As long as you can seamlessly and safely generate your own wind or solar power to help run your lights or heat your water, the more customers who do it, the better.

Some of your relatives who live in Los Angeles have gotten even more adventurous. They got together with their utility and created their own plan: the "Green Friends and Family Plan." They leased three parking spaces behind the elementary school down the street. Then they leased from Southern California Edison a Bloom Energy reversible fuel cell machine and connected it to their homes. It is a big black box about the size of a passenger van, and it saves money, energy, and the environment in lots of ways. It can take electrical energy from the grid late at night, when power is cheapest, and, via a process of electrolysis, convert water into hydrogen and store it in a storage tank, and then convert it back to electricity for you and your neighbors to power homes or charge cars during peak hours, when electricity is twice as expensive. It can take hydrogen or solar power and convert it into electricity—and the only "waste" is clean water. You can even feed it agricultural waste, and it will use a little built-in furnace to convert that waste into hydrogen and then electricity. Classes at the elementary school—which shares the electricity with the neighbors—compete over who can feed the Bloom Energy box the most biomass and generate the most electrons.

Your utility is happy to be offering these services, because it's now making money from each one—rather than just selling cheap, dumb electrons at an all-you-can-eat buffet. The regulators are happy to see this, because they believe these services benefit customers, help the environment, and relieve stress on the grid, so that more costly power plants are not necessary.

What you don't see, but what is hugely important, is that this Energy Internet–smart grid enables your utility to use more renewable power. As noted earlier, in the old days utilities always built their generation systems to ensure that they could handle all the air conditioners running on the four hottest days of the summer, when energy demand peaked. They did this, in part, by predicting demand and scheduling the supply a day or an hour ahead of time. They got very, very good at that. But just in case they miscalculated, or ran into an unexpectedly long and intense heat wave, they also overprovisioned their grids so that, ideally, no one would be denied electricity on the hottest days. They did that by building extra power plants. It sounds smart—but it was anything but efficient. Imagine that *you owned a factory that made greeting cards. If you acted like the utilities did, you would build one $10 million factory that would run at capacity every day to handle your standard business. And then you would build another $10 million factory just to handle your excess business on the week before Christmas and the three days before Mother's Day, Father's Day, and Valentine's Day. The rest of the year, this second factory would produce nothing, but all the machines would be on standby low power, just in case there was a sudden run on birthday cards. That is a really inefficient way to use capital, but that's how we managed our utility grid for a long time.*

Now that the smart grid is in place, though, we can control demand. Because either the utility or the customer is able to optimize when power is used, so many more people automatically run things later at night when rates were cheapest and fewer things in the daytime when they were more expensive. The Energy Internet has become so smart about when you want to use power or when it would have to sell you power or when it could buy power off your car battery or home solar system that the load has become much more constant 365 days of the year. The "flatter" that any utility grid can make its load profile throughout the day for all its customers—so that its peaks are not very high or are eliminated altogether—the fewer backup power plants it needs to build or operate. It is, in effect, substituting energy efficiency for new power generation.

That is what the Energy Internet has made possible. But it didn't only increase energy efficiency. It has also made large-scale renewable energy practical for the first time ever. Why? Because the flatter your utility's load profile gets, the more it is able to go out and buy or generate renewable energy and sell it to you and your neighbors instead of energy powered by coal or gas. In 20 E.C.E., Southern California Edison now derives more than half of its power from two vast renewable energy sources—wind and solar—while using a mix of nuclear, natural gas, and carbon-sequestered coal for the rest. SoCalEd has built huge wind farms in Wyoming and Montana, and contracted with many smaller independents along the way. The Wyoming farm is so vast it is a tourist site, like the Hoover Dam, with turbines as far as the eye can see.

The smart grid made all this large-scale renewable energy practical. In the old days, the big drawback of wind and solar was that they were variable. The sun was there during the day, but not at night. The wind in most parts of the country tends to blow hardest at night and early in the morning—in other words, during off-peak hours. The energy produced by these clean renewable resources could not be cost-effectively stored using existing battery technologies. The most viable storage mechanism used by the power industry was pumped storage—using energy to pump water up a hill during the night and generating electricity via falling water during the day. The problem was that there were relatively few pumped hydro projects in this country, they were very expensive to construct, and you expended three units of energy moving water up the hill at night for every unit you got back the next day. Those facts made it very hard for any utility to depend on wind or solar for more than 20 percent of its power supply, because it had to be backed up with extra natural gas power plants for those days when the sun didn't shine or the wind didn't blow.

But now that we've moved to the Energy Internet—the smart grid—utilities can run your refrigerator or adjust your thermostat in line with when the wind is blowing or the sun is shining. It can match the supply with the demand. Therefore, it can use more of these renewable power sources at much lower cost. When clouds block out the sun or the wind dies down, the utility's smart grid lowers demand by raising prices (so your SBB decides not to do the laundry then) or by adjusting your home temperature settings. And when the sun is shining brightly and the wind is howling, the utility runs your dryer at the lowest price. So there is now a direct correlation between how smart your grid is, how much energy efficiency it can generate, and how much renewable power it can use.

Like all revolutions, though, this one changed many things at once. When the smart grid extended into a smart home all the way to a smart car, it created a whole new energy market on the other side of your electric meter. In the old days, there was no market beyond the raw dumb electrons that came into your house. Everything stopped at the meter, and you just paid the price calculated at the end of the month. But once your appliances became smart, and a Smart Black Box was introduced into your house, a market was also created beyond your meter and throughout your home, and, more broadly, inside every factory and business around the country.

Some utilities have decided to step into that market and help you optimize your smart home to get the most cooling, heating, and other electricity services from the cleanest, fewest, cheapest electrons. Most utilities, though, have decided to serve as facilitators for this whole new industry—energy efficiency service companies, EESCs. These EESCs have emerged—just like Internet providers that crept up alongside the traditional phone *companies—to help you optimize the smart grid for your home. The utility has created this market by telling you, the customer, that it will give you big discounts, even subsidies, for installing energy-efficient appliances or weatherizing your home to lower your consumption of electrons. This is because the government regulator has cut a new deal with the utility, whereby the utility is now being paid for how much energy it can help its customers save—rather than consume! (I will explain this in detail in chapter 12.) The EESCs then come in and help you do that job.*

Just the other day, a salesman from General Electric's energy efficiency service company came to your door. Your home is twenty years old. The General Electric EESC man offered this deal: First, for free, they would give your whole house an efficiency checkup. They would bring in equipment to pressurize your entire home and show you where all the heat and air-conditioning was leaking from ducts that had not been connected properly and therefore were just warming the crawl spaces—much to the enjoyment of the mice. Then they would borrow the money to pay for sealing all the leaks in the ducts and fissures in your roof that had been silently draining energy from your house and raising your monthly bills by 30 percent. They would also install more energy-efficient appliances. You don't need to put down any money up front. The EESC would share with you the money you saved on your monthly electric and gas bills and the money the EESC would earn from selling the carbon credits on the global market for reducing your carbon footprint. The General Electric EESC takes 75 percent of the savings, using 50 percent to pay off the loan, and keeps 25 percent as profit. And you get the other 25 percent savings. Your home is now more energy efficient and has a higher resale value. Meanwhile, the Sears EESC just dropped off a pamphlet offering you the same deal with a 60–40 split! Because the cash flow from all these efficiency deals is very predictable, the EESCs can sell them to investment banks, which turn them into green savings bonds.

After you showered and ate breakfast, you decided to head for the office for your first meeting. This involved taking a short walk—about twenty paces—down the hall to your home office, holding your Smart Card in your hand. Your Smart Card, which is sponsored by Visa and United Airlines Mileage Plus, looks just like a credit card, only slightly thicker. You start your workday by putting it into the docking bay of the Sun Ray terminal, made by Sun Microsystems, on your home office desk.

That Sun Ray terminal uses only four watts, compared to fifty watts or more in your standard PC. The reason is that there is no hard drive sucking up energy. The Sun Ray terminal is just a screen with a slot beneath it, but as soon as you put the Smart Card into the slot, it connects you to the "network cloud," where all your software programs, e-mail, Internet applications, and personal files are located. The "cloud" is a data center, packed with servers, that is located close to a dam on the Columbia River, which is providing it with clean hydropower to run all your programs (and those of millions of other people) and to cool all those servers.

The smart lights in your office, triggered by motion sensors, went on as soon as you walked into the room, as did the air conditioner. No electricity is consumed in the room when you are not there. Every device, every new home, and every new building is now built with steadily rising efficiency standards from day one. In the 2007 energy bill, President George W. Bush effectively outlawed the Edison incandescent lightbulb, phasing it out by 2014, because it converts 90 percent of its energy into wasted heat—which we all noticed when we burned our fingers trying to remove a bulb before it cooled down. It has been replaced by a smart compact fluorescent. With one-fourth the electricity consumption, it not only reduces the energy required to produce light, but also reduces the energy required to cool your office, which was being warmed by the excess heat emanating from all your incandescent bulbs.

On your desk, next to the Sun Ray terminal, you have a six-watt desk lamp. That's right, only six watts—because this lamp uses a light-emitting diode and little mirrors to give you intense focused light, the equivalent of 100 watts, but at 6 percent of the energy use. The same is true for the appliances throughout your house. Your refrigerator is so efficient that it represents the electricity equivalent of a twenty-watt lightbulb. Your television, TiVo unit, and treadmill all shut down completely, no longer draining power when not in use.

Normally, your company encourages you to work from home as much as possible. But today, on the Sun Ray terminal, you found a message from your boss saying that a teleconference would be held downtown at 10:30 a.m., between your management team and your colleagues in Chennai, India, where your company is involved in a huge real estate development. At 9:45 a.m. you get in your Ford Mustang RESU. It is a plug-in hybrid electric that gets the equivalent of 100 miles per gallon. Plug-in hybrid electric vehicles are like regular hybrids but with larger batteries and the ability to recharge from a wall outlet. As a result, all your local travel is electric, but you always have a gas tank backup. The battery is charged every night, or whenever it needs juice, and, like your dryer and other appliances, automatically interacts with your electric utility to buy the lowest-cost electrons available during the depths of nighttime off-peak hours.

As you set out to the office, the GPS map in the car flashed a message that there was an accident on the highway that you normally use to get to the office and proposed an alternative route.

To enter into the downtown area, you had to pass through an electronic gateway, which automatically charged you $12 for entering the city between 10:00 a.m. and 2:00 p.m. (It costs $18 at rush hour.) This is another reason you work from home as often as you can, carpool, or take the bus to work. It's all part of the new congestion-pricing system that has dramatically reduced the number of cars coming into the city and thereby created more room for electric buses and other forms of mass transit, which can now take more people to more places faster than ever before. Your city's new mayor actually won the election with the motto "Price the road and clear the traffic." You don't need to be a rocket scientist, said the mayor: "If you want fewer CO_2 emitters, charge people money for emitting CO_2. If you want fewer cars on the roads during certain hours, charge people money for using them." It works everywhere it has been tried.

When you arrived at the office, you docked your car at a parking ramp where you can both charge your car battery and sell electricity into the grid. There is a universal two-way plug in every home and parking lot in America now. You decided to park at this ramp after it won a bidding contest against the parking ramp around the corner. These bidding contests between parking ramp owners are now very common. Your ramp won by throwing in four free-parking days a month and a car wash every Friday.

Why does the ramp owner want you to park there so badly? Because you will be sharing with him the money you earn from selling extra electrons back to the grid. The entire roof of the parking ramp consists of solar panels that create clean electrons, which are then sold to the batteries of all the cars on the ramp. The owner calls it "e-gasoline." The parking lot's name is Bill's Artificial Oil Field. So the lot owner is both in the parking and the energy-generating business. At 2:32 p.m., when the temperature hit 87 degrees, your car, which still had most of its electrons from last night's charge, made a calculation that energy prices had moved up on the smart grid to a point where it was time to sell some electrons. Your smart car calculated how many electrons you would need to drive to your normal Wednesday after-work chores—to take the kids to soccer practice and stop at the grocery store—and saved 10 percent more just in case you altered your routine. Then it put a sell bid of 40 cents a kilowatt-hour out to the utility. SoCalEd bought 5 kilowatt-hours off your car battery through the universal plug. This helped the utility meet its peak load demand and keep its load profile flat, while you and the garage owner both made money. In this case, you made $2. The parking lot operator, who provided the solar panels and the plug connecting your car to the grid, also got a small cut of that. So far this month your car battery has earned you $24 selling and buffering electricity. At the same time, it cost you only $47 this month to charge your car with electricity, because you were usually charging at home at night at low off-peak rates and selling it during the day at peak rates. It means you are driving for the equivalent of about $1.50 per gallon. People still drive less and use more mass transit—because congestion pricing, which funds better mass transit, induces them to do so, rather than high oil prices that fund petrodictators.

While at the office, your boss gathered together the entire management team responsible for designing smart housing for a new suburb in Chennai. You met with your six Indian counterparts in Chennai for three hours to go over everything from financing to architectural problems. Once, such business would have had to be conducted face-to-face, with at least some of you flying over to Chennai, expending considerable time, money, and energy. Not anymore.

This three-hour meeting was held virtually through Cisco Systems' TelePresence system, over the Cisco network, in which your team sat in a studio and the other team was vividly illustrated on a wall-size TV screen in 3-D. The Cisco TelePresence makes people look and sound just like they do in person, offering life-size images of each meeting participant, high-definition video, and spatial audio, which creates the dynamic of voices coming directly from the participants. It is so realistic you all felt as if you were at the same table in the same room, even though you were half a world apart. In fact, it was all so realistic, and the images so life-size, that when the meeting ended you got up and tried to shake hands with someone on the screen, eliciting laughter all around.

After the meeting, you returned home and docked your car back in the garage, around 4:00 p.m. As you were mowing the lawn with your all-electric mower, your kids came home on their hybrid electric school *bus, just another big rolling energy storage unit that actually makes money for the school district by storing and selling clean electrons the way you do.*

The neighborhood school is now a dual-use education and commercial center—a DUECC. That is, the school kitchen, as soon as it is finished serving lunch, is taken over by Einstein Bros. Bagels. Instead of building their own new bakery, the bagel company uses the school's kitchens from 3:00 p.m. until 6:00 a.m. the next morning to bake bagels and deliver them to their outlets and grocery stores throughout the city. Dual-using has become a huge trend, saving enormous amounts of electricity, land, and new construction, and, by the way, earning the school extra cash to hire more teachers. Domino's Pizza also uses idle school kitchens during after-lunch hours for making and delivering pizzas throughout the city. Domino's has not leased or built a new commercial kitchen in years.

The school is also a net-zero building. It was designed and built so that all the parts—walls, windows, the lighting system, the water-handling system, the air-handling system—are both individually and collectively super-energy-efficient. At the same time, the external roof and walls of the school building are a mini-utility—a combination of solar panels, solar thermal generation, and passive lighting through smart windows that let maximum light in during the day to replace bulbs. As a result, during working hours, the school is a net energy producer, and it sells its excess electrons into the grid. At night, when Einstein is cooking the next day's bagels in the kitchen, the school buys whatever electricity it needs from the grid at low, off-peak rates. At the end of each month, its utility bill reads "net zero." You cannot get a building permit in your city any longer unless your building is energy "net zero."

Why are net-zero buildings, and dual-use, such a big deal? Well, here's a fun fact: The production of cement worldwide—the heat that has to be generated to roast the limestone and the CO_2 that is emitted in the process—releases almost as much CO_2 into the atmosphere as all the passenger cars in the world. So just throwing up dumb cement buildings is a huge energy drain and carbon dioxide generator. Once we realized how much of both we could save from smarter cars and smarter buildings, building standards became as important as mileage standards.

I am sure that what I have described above sounds far-fetched—like something out of a *Jetsons* cartoon or a science fiction novel. Well, it's not fetched from very far. A simple prototype of this Energy Internet was deployed in 2007 in Washington State's Olympic Peninsula, in an experiment organized by the Department of Energy's Pacific Northwest National Laboratory, in partnership with the Bonneville Power Administration and local utilities. On November 26, 2007, MSNBC ran a story about the preliminary results, headlined "Smart Appliances Learning to Save Power Grid." The story noted that "as part of the experiment, the researchers found that they could cut the peak electricity load among participating homes by half for three days in a row." It quoted Rob Pratt, the lab's program manager for a multiagency collaboration dubbed GridWise, as saying:

> "That was astounding." . . . One homeowner, Jerry Brous of Sequim, Wash., who signed up for the program as soon as he heard about it on a local radio station, said that his electricity load dropped by 15 percent, and he compiled his own Excel spreadsheet to determine the percentage of power flowing to his water heater, heat pump and dryer to pinpoint how he might save even more. He also received quarterly checks from the program reflecting his savings, including a recent one for $37. During several camping trips, Brous could tell his house to "go to sleep or wake up," simply by logging onto an Internet site and remotely turning his heat and hot water heater on or off.

The article explained that

> in the Brous household and others throughout Washington's Olympic Peninsula, smart water heaters and thermostats provided updated electric prices about every five minutes, depending on what was available and needed. Homeowners could adjust their settings to decrease power consumption and save money during peak demand or override the controls at any point, like when they were hosting dinner guests or a fussy relative . . . Richard Katzev, an expert on social and environmental behavior and president of Portland, Ore.,–based Public Policy Research, said merely providing more information to consumers would be ineffective without also giving them incentives to act. Homeowners will readily accept money-saving devices that require fairly easy lifestyle adjustments, he said, like delaying a dishwasher or dryer run to obtain cheaper rates.

The article went on to say that

researchers spent an average of $1,000 on appliances, equipment and monitoring capabilities for each of the roughly 200 homes participating in two related studies. But for more widespread and routine residential use, he expects the upfront costs to run about $400 to $500 and potentially less if computer chips can be built into the appliances before they leave the factory. "If this becomes cheap enough, even your coffeemaker can help the grid out," [Pratt] said. And if eventually adopted throughout the country, the energy-saving appliances could translate into savings of about $70 billion in new power plant construction and power distribution costs over 20 years.

Speaking of coffeemakers helping out the grid, Pratt and his colleagues Mike Davis and Carl Imhoff at the Pacific Northwest National Laboratory in Richland, Washington, gave me a demonstration when I visited them. They took me into a room that is set up like a home kitchen/laundry room, with a washer, dryer, water heater, refrigerator, and coffeemaker. Each device was outfitted with a special chip designed at PNNL. It is called a "Grid Friendly Appliance" controller, or GFA. This Grid Friendly controller is a 2-by-2.5-inch circuit board that can be installed in refrigerators, air conditioners, water heaters, and various other household appliances. It monitors the power grid and turns appliances off for a few seconds to a few minutes—without ruining the appliance—in response to power grid overload or commands. When power plants cannot generate enough power to meet customer needs, Grid Friendly Appliances reduce some of the load on the system to balance supply and demand.

So when I came into the mock kitchen, they had everything running, including the refrigerator with the door open. On a digital overhead display, they had a readout showing how many kilowatts all the appliances were using at full blast. It was very noisy. Then they dropped the electricity into the kitchen by 70 percent. What was amazing was that all the devices appeared to continue to run, making almost the same amount of noise, but they were using 70 percent less electricity. How? The Grid Friendly Appliances sensed the power dip and reacted by cutting off portions of their load. For instance, the dryer turned off the heating element but kept the drum turning; the hot water heater's heating element went off, but there was enough hot water stored in the tank that if you were in the shower you never would have known. In the refrigerator, the defrost

cycle was interrupted, but if you opened the door the light remained on and your food would easily have stayed cold for the two or three minutes in which the grid was under stress and the power got dialed down. These grid-friendly circuits cost only $25 per appliance, and the price would surely plummet with mass production.

The beauty of this technology, which is now being pilot tested in bigger communities, is severalfold. First, these sorts of power dips happen on your grid a few times a week. You just don't know it, and the reason you don't know it is because your utility protects against it by having a spare power plant or two spinning all the time, even when they are not producing electricity, so that its power can be drawn upon instantly whenever there is a dip. That is called "reserve requirement," and if the reserve plant is a coal plant, it is spitting out CO_2—just so you don't experience a dip.

If we could manage these dips by controlling demand, just dialing down appliances rather than always adding extra supply, we could save energy and money and cut back CO_2 emissions. "From the beginning of the grid, we have tried to solve every problem from the supply side with new technology—we've never been able to do it from the demand side with new technology," said Mike Davis, the associate director for PNNL's Energy Science and Technology Directorate. "Now we have the technology to do it. If someone wants to turn off the heating element in my coffeepot for a couple minutes every day—and do it with millions of other homes—so we don't have to have extra coal-fired power plants, I'm good with that."

The model that I envisaged above, and the model that Davis and his colleagues tested out, would involve a revolutionary change to the utilities industry. Utilities, instead of limiting their vision from the power plant to your home electricity meter, would be wholly transformed. Their universe would stretch from the generation of clean power on one end right into your home appliances, your car battery, and even the solar panels on your roof. Rather than just being a seller of dumb and dirty electrons, it would be an enabler of this whole smart grid–Energy Internet system. And it would make its money from optimizing this system.

Jim Rogers, the CEO of Duke Energy, based in Charlotte, North Carolina, likes to say that rather than spend $7 billion on building a new nuclear plant, he would rather the regulators let him spend that same amount of money building out a smart transmission grid and helping his customers to install solar panels on their roofs, Smart Black Boxes in their homes, smart batteries in their cars, and Grid Friendly chips in their appliances, and then have Duke Energy maintain and service every aspect of that network.

"For a hundred years we defined the boundaries of our market as being from the generator to the meter on the wall outside your house," said Rogers. Going forward, "I want that market to be from the generator to our customers' rooftops and to the energy applications and energy networks embedded in our customers' homes and offices and cars. That is where the real savings will come—from optimizing those energy networks and applications . . . I have to take my grid and make it smart and make everyone's home into a smart home and everyone's factory into a smart factory and then optimize them all so everyone gets the most service for the least money and least amount of CO_2."

That would be a very different job for utilities—from running an all-you-can-eat-for-five-dollars electron buffet to optimizing an Energy Internet. But that is the future.

And as Jeff Wacker, the EDS strategist, likes to say: "The future is with us, it's just not widely distributed yet." He is right in the sense that we can see today what the future could look like. We can see the technologies taking shape that could make it happen, but we still need a few key breakthroughs to get that future widely distributed.

The Energy Internet I've described, if we can get it built, has the potential to give us more growth with fewer power plants, better energy efficiency, and more renewable energy, like wind and solar, by smoothing out the peaks and valleys in energy demand. If we could just add another breakthrough on top of that—inventing a source of energy that would give us abundant, clean, reliable, and cheap electrons to power this Energy Internet and that would dramatically reduce our usage of coal, oil, and natural gas—the revolution would be complete. Then you would be feeding clean electrons into an energy-saving smart grid, into a smart home, and into a smart car.

That, when it happens, will be the great energy transformation. It will be like two giant rivers coming together—the IT revolution and the ET revolution. And when it happens—when it *really* happens—it will unlock more human potential, more innovation, more possibilities to lift people out of poverty in a sustainable way, than you can possibly imagine. I just want to live long enough to see that day dawn. The next chapters describe how we can make it happen.

ELEVEN

The Stone Age Didn't En[d Because] We Ran Out of Sto[nes]

Recently reports have been current in certain newspapers th[...] the inventor, has at last perfected the storage battery, and tha[...] trically propelled vehicles, costing little to buy and next to n[...] on the market. The same story has appeared regularly for year[s ...] pear to have advanced much.

—*International Herald Tribune*, November 1, 1907

If I'd asked my customers what they wanted, they'd have said [...]

—Henry Ford

The city of Tianjin, China, is home to man[...] makers, and in September 2007 I was in[...] China "Green Car Congress" there. Yes, C[...] steadily improving its own auto mileage and poll[...] holds a conference to talk about the latest in gr[...] Who knew? The venue was the Marriott in Tianjin[...] mostly Chinese auto industry executives—some pr[...] guys—who listened to my remarks, via translatio[...] thought hard and long beforehand about what to [...] might stimulate their thinking and give them a pe[...] heard before. In the end, I decided to go right for t[...] thrust of my talk was as follows:

"Every year I come to China and young Chines[...] man, you Americans got to grow dirty for 150 years—